US Army Corps of Engineers
Construction Engineering Research Laboratory

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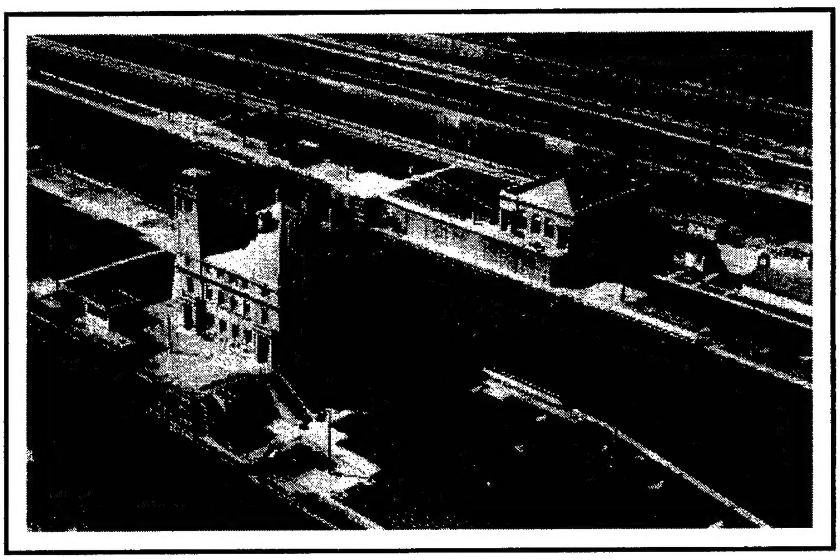
August 1999

Recommendations To Improve Energy Efficiency at the Soo Area Office, Sault Ste. Marie, MI

Larry Lister and Martin J. Savoie



In terms of energy consumption, the Soo Area Office, Sault Ste. Marie, MI is the largest facility under U.S. Army Corps of Engineers Detroit District oversight. The entire facility at St. Mary's Falls Canal is operated and maintained by the Detroit District, under the supervision of the Soo Area Engineer. Energy supply for the facility is unique because the U.S. Hydroelectric Power Plant is located just north of the locks. The installation consumes about 3 percent of the energy from the plant. Natural gas provides most of the space heating requirements via cast-iron sectional hot water generators in the larger buildings, unit heaters in small buildings, and fire-tube steam boilers in the steam plant.

The U.S. Army Corps of Engineers Detroit District requested the U.S. Construction Engineering Research Laboratory (CERL) to assess potential energy efficiency improvements at the Soo Area Office. This study evaluated the facility for energy efficiency and recommended improvements in energy efficient operations.

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In terms of energy consumption, the Soo Area Office, Sault Ste. Marie, MI is the largest facility under U.S. Army Corps of Engineers Detroit District oversight. The entire facility at St. Mary's Falls Canal is operated and maintained by the Detroit District, under the supervision of the Soo Area Engineer. Energy supply for the facility is unique because the U.S. Hydroelectric Power Plant is located just north of the locks. The installation consumes about 3 percent of the energy from the plant. Natural gas provides most of the space heating requirements via cast-iron sectional hot water generators in the larger buildings, unit heaters in small buildings, and fire-tube steam boilers in the steam plant.

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Foreword

This study was conducted for Commander, U.S. Army Corps of Engineers Detroit District, under the "Small Problems Program"; Work Unit, "Energy Efficiency Issues for Soo Area Office." The technical monitor was Don Erfourth, CELRE-CO-SO.

The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), U.S. Army Construction Engineering Research Laboratory (CERL). The CERL principal investigator was Martin J. Savoie. Larry M. Windingland is Chief, CECER-CF-E, and L. Michael Golish is Chief, CECER-CF. The CERL technical editor was William J. Wolfe, Information Technology Laboratory.

The Director of CERL is Dr. Michael J. O'Connor.

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1 Introduction

Background

In terms of energy consumption, the Soo Area Office, Sault Ste. Marie, MI is the largest facility under U.S. Army Corps of Engineers Detroit District oversight. The entire facility at St. Mary's Falls Canal is operated and maintained by the Detroit District under the supervision of the Soo Area Engineer. The facility has four locks: MacArthur, Poe, Davis, and Sabin. The Poe lock has the largest capacity of the four locks and is the most active. The locks serve many different types of vessels, varying in size from small passenger vessels and work boats, to large ships carrying more than 72,000 tons of freight in a single cargo. Approximately 12,000 vessels pass through the locks each year. A proposed new lock is envisioned in the area now occupied by the Davis and Sabin Locks.

Energy supply for the facility is unique because the U.S. Hydroelectric Power Plant is located just north of the locks. The 20 megawatt (MW) plant generates over 150 million kilowatt hours of electric power each year. The first priority for the power generator is the lock operations. The remaining power is purchased by a private power company (Detroit Sault Electric Co.) and distributed to homes and business in Sault Ste. Marie and surrounding communities. About 3 percent of the energy from the plant is consumed by the installation. Primary use for electric power on the facility includes:

- exterior and interior lighting
- floating plant equipment
- domestic water heating
- interior space heating (remote buildings only)
- air compressor plant
- dewatering pumps for lock maintenance
- process loads for hydroplant and steam plant operations
- electric vehicle charging
- electrically-driven lock gate operators
- building loads (receptacle loads for typical office equipment).

Natural gas provides most of the space heating requirements via cast-iron sectional hot water generators in the larger buildings, unit heaters in small buildings and fire-tube steam boilers in the steam plant. A new steam plant was con-

structed in 1996, located between the Poe and Davis locks, to generate high pressure steam for operating two 70-ton stiffleg derrick hoist machines for the Davis and Sabin Locks, to deice the locks during the winter, and to provide heat to facility construction projects. An ancillary use is to heat the administration and Davis buildings.

At the request of the Commander, U.S. Army Corps of Engineers Detroit District, U.S. Construction Engineering Research Laboratory (CERL) staff made a site visit to the Soo Area Office, Sault Ste. Marie, MI to assess potential energy efficiency improvements.

Objectives

The objectives of this study were to evaluate the facilities at the Soo Area Office, Sault Ste. Marie, MI for energy efficiency, and to make recommendations for improvements in energy efficient operations.

Approach

1. CERL engineers made a site visit to the Soo Area Office on 15 April 1999.
2. Lock personnel gave CERL personnel a detailed tour of the facility.
3. CERL engineers surveyed the facility's electrical energy use, its buildings, floating plants, central heating plant, and air compressors.
4. Soo Lock engineering, and operations and maintenance personnel were interviewed.
5. The condition of the facility components was summarized, and recommendations made for improved energy-efficient operations.

Scope

This study specifically focused on conditions at the Soo Area Office. However, some information in this study may be applicable to similar lock-and-dam facilities.

Mode of Technology Transfer

This information will be forwarded directly to the Corps of Engineers Detroit District, Soo Area Office, Sault Ste. Marie, MI, and will also be made publicly available through the CERL Internet website at the following URL:

http://www.cecer.army.mil/techreports

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 yd	=	0.9144 m
1 sq in.	=	6.452 cm^2
1 sq ft	=	0.093 m^2
1 sq yd	=	0.836 m^2
1 cu in.	=	16.39 cm^3
1 cu ft	=	0.028 m^3
1 cu yd	=	0.764 m^3
1 gal	=	3.78 L
1 lb	=	0.453 kg
1 hp	=	9.803 kW
1 psi	=	6.89 kPa
°F	=	(°C x 1.8) + 32

2 Electrical Energy Use

The Soo Area Office Point of Contact (POC) was Don Erfourth, tel. (906) 635-3468

Description

The primary source of end-use energy at the Soo Area Office is electricity. The Soo hydroplant generates 20 MW of power that is sold to and feeds the upper peninsula (Detroit Sault Electric Co.) grid. About 3 percent of the energy from the plant is consumed by the installation. End-use applications include:

- Exterior lighting, which currently uses high pressure sodium luminaires.
- Floating plant support, which includes all electrical power required when docked. End-uses are electrical space heating, equipment (strip) heating, lighting, and all on-board operations such as electronic (receptacle) loads and equipment (connected) loads (pumps, hoists, cranes, etc.).
- Domestic water heating in most buildings. Chapter 3 includes more detail on the buildings' energy use.
- Interior space heating (remote buildings only). Chapter 3 includes more detail on the buildings' energy use.
- Interior lighting, which currently uses energy-efficient T12 technologies.
- Air compressor plant (3 x 350 hp), which is used for hydraulic lock gate operations, and also seasonally for bubbling air near the lock gates to keep them clean of ice and snow and for some process compressed air loads.
- Pumping, for which large pumps are used intermittently to dewater the locks for maintenance.
- Miscellaneous process loads, which include hydroplant and steam plant operations, electric vehicle charging, electrically-driven lock gate operators.
- Miscellaneous building loads, which include receptacle loads such as office equipment, copy machines, etc.

The marginal cost of this electric energy is quite low, which negatively impacts the economic cost-effectiveness of electrical energy efficiency projects. In spite of this impediment, Mr. Erfourth has initiated and executed a large number of energy-saving projects. These include a base-wide mercury-to-high pressure sodium (HPS) conversion that cut exterior lighting energy use by over 60 percent

with no impact on exterior lighting levels. Lighting in the Administration Building and the Davis Buildings was replaced 3-4 years ago and the most energy-efficient T12/magnetic ballast fluorescent technologies available at that time were used in those applications. Future interior lighting upgrades (if undertaken) should consider T8/electronic ballast technologies, which are now technically mature and have become the Government standard for new construction. Based on economics, and the small sizes and distributed locations of many of the buildings, further replacing existing interior electric heating with other fuel-based heating sources is not recommended. Better thermostatic and/or time clock control of these electrically heated structures are and should continue to be considered on an individual basis based on occupancy and the need for maintenance or replacement of faulty systems.

Individual behavior patterns can dictate the efficient use of electricity to a large extent because humans directly control many of the end uses themselves. A significant part of the installation Energy Manager's job (on larger posts) is in fact to teach energy awareness. Discussions with personnel across the installation indicated that the diligence Mr. Erfourth has shown toward energy efficiency in their departments has impacted their behavior and subsequently has reduced electricity use across the installation. This personal effort is a large part of why the Soo Area Office exhibits such exemplary energy behavior patterns. While there is no way to account for the amount of energy being saved by this individual, his impact was evident and his performance is to be highly commended. He appears to view every project being implemented at The Soo s an opportunity to increase energy efficiency

Recommendations

Replace existing fluorescent lighting systems with T8/electronic systems at the next time of building rehab or wide-scale lighting replacement. Replacement of the functioning T12 luminaires is not warranted on economic grounds alone.

Consider increasing light levels in the utility tunnel, and installation of a lighting control system for the utility tunnels running parallel to the locks. Such a system must be carefully designed to allow workers to not be trapped inside the tunnels if lights go out. This is unlikely to have a positive economic payback, but these tunnels reportedly have lights on quite often when there is nobody working or traversing the tunnel. Light levels were slightly restrictive in the tunnel, allowing plenty of light to walk from point-to-point in the tunnel but not enough in many places to do close work or perform repairs

Continue to monitor space heater control condition in remote structures to ensure that controls are working as intended and are not set too high. Install DDC monitoring and control system for floating plants operations (see separate section below).

Upon failure of existing systems, replace warehouse lighting (Figure 1) with T8/electronic ballasted luminaires. The 8-ft fixtures should be replaced with 4-ft strips. It is recommended that the system be master/slave wired so that a single ballast is driving 3 or 4 lamps.

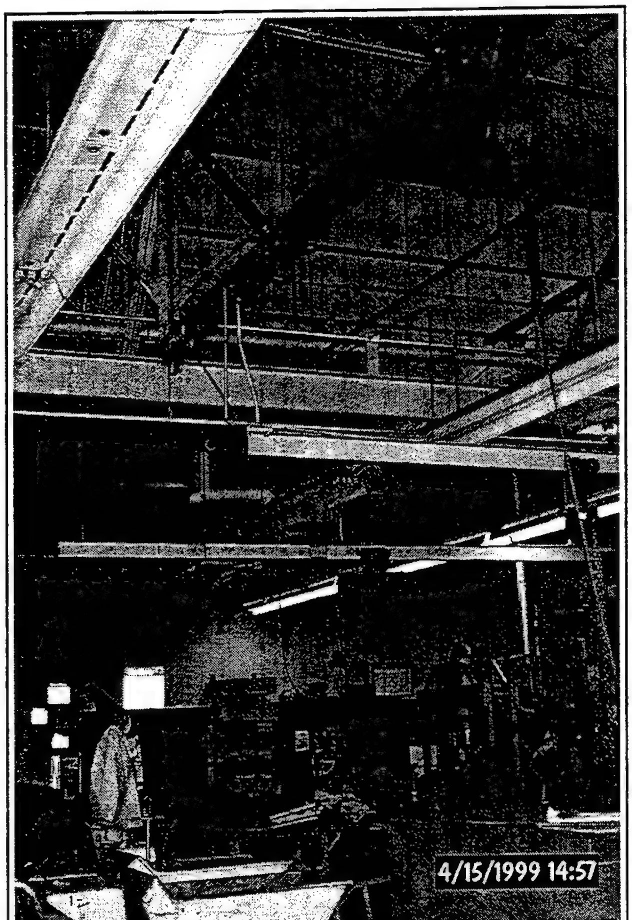

Figure 1. North warehouse lighting.

3 Buildings

The following buildings were toured and inspected by CERL engineers:

- Administration Building (incl. control tower)
- Davis Building
- North Warehouse
- South Warehouse
- Hydroplant
- Steam Plant (new)
- Boathouse.

The first four main buildings cited above comprise a large percentage of the normally occupied and conditioned square footage. A majority of the office-based personnel work in or are based out of these four buildings. A short summary of the observations in these areas follows.

Administration and Davis Buildings

Description

These historic buildings house a number of administrative and engineering staff at the Soo. The Administration Building (built in 1896) occupies an area of 23, 292 sq ft, and the Davis Building (built in 1914) covers 8898 sq ft. The Administration Building also contains the control tower used to oversee navigation and lock operations. These buildings are heated by steam radiators connected to either central plant steam or a backup steam boilers installed in 1988. The backup boiler is used during the late spring and early fall when the seasonally-operated process steam plant is no longer in use.

Assessment

The use of the "end-of-pipe" steam by both the Administration and Davis Buildings is an extremely efficient way to heat these buildings during the coldest months. The building heating system appeared to be in very good condition. Building renovations currently underway will replace the old windows with energy efficient units. Light-

ing systems are described in the above section. No further energy conservation efforts are warranted in these buildings.

North Warehouse and South Warehouse.

Description

New boilers have been installed to serve the North and South Warehouses. The existing North Warehouse brick building envelope, along with its overhead doors and windows is rather leaky. Operation of this building requires frequent overhead door opening year-around.

Assessment

Because of this use pattern, a more energy-efficient approach to space heating would be to replace the overhead steam-fed unit heaters (Figure 2) with gas-fired infrared heaters. Note, however, that the cost-effectiveness is probably not worthy of energy conservation funding. Lighting is of older T12 type, with a number of 8-ft luminaires still in place. Replacement with T8 and electronic ballasts is recommended at the time of the next building renovation. The "**Recommendations**" section in Chapter 2 (p 11) gives further details.

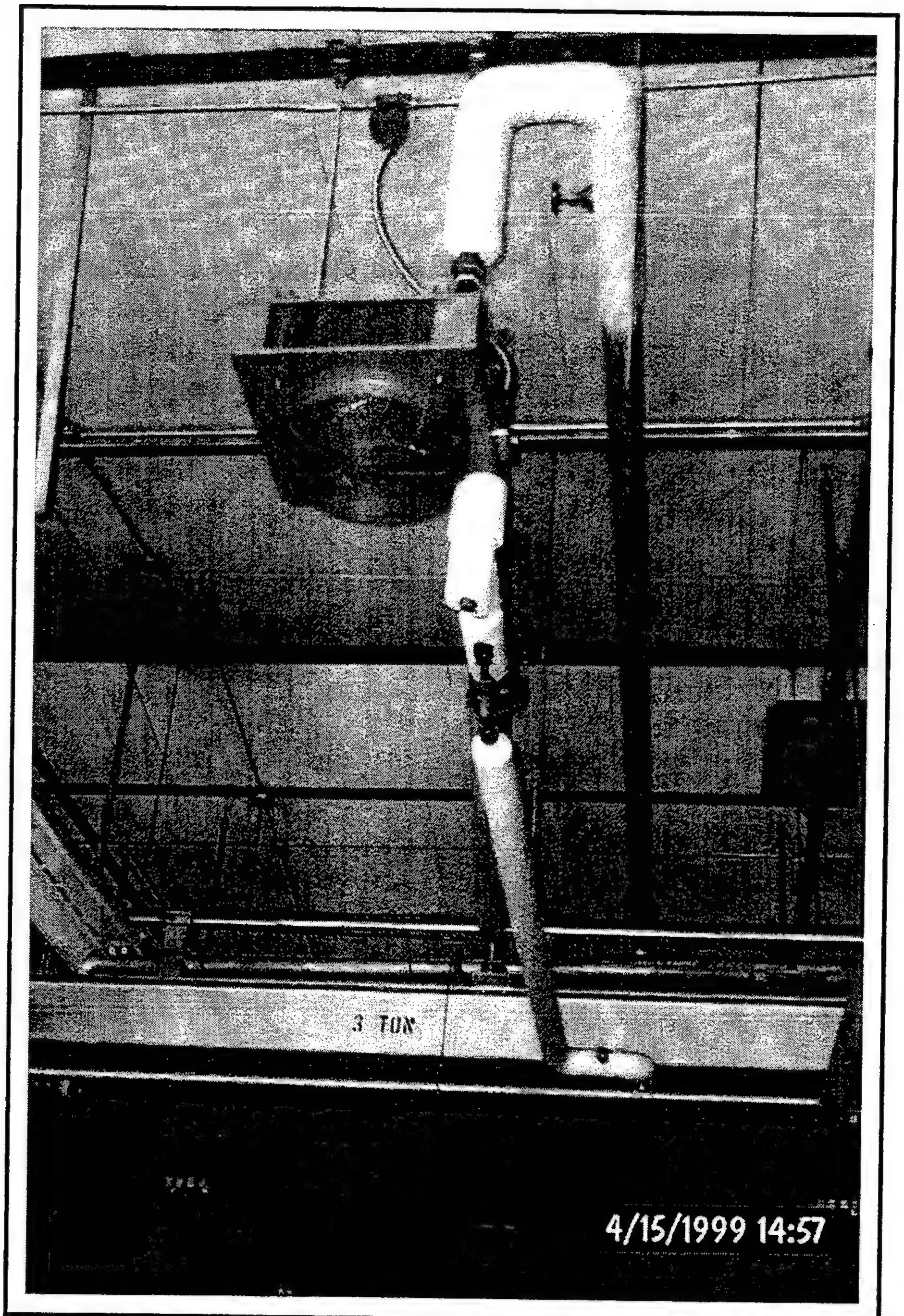

Figure 2. Warehouse unit heater.

4 Floating Plants

The POC for the floating plants was Ed Hallquist, tel: (906) 632-3311.

Description

The fleet of floating plants used by Soo Area Office personnel consists of six boats that are used on the river during normal workday activities and are docked at the installation on nights and weekends (Figure 3). In winter, when the channel is closed, most of the boats are docked until spring. There is dock space for two boats under cover in the boathouse (Figure 4). While docked, these boats are connected to installation electrical power at a series of pedestals. Workers remain on board the boats and work during business hours throughout the winter.

Figure 3. Floating plant equipment.

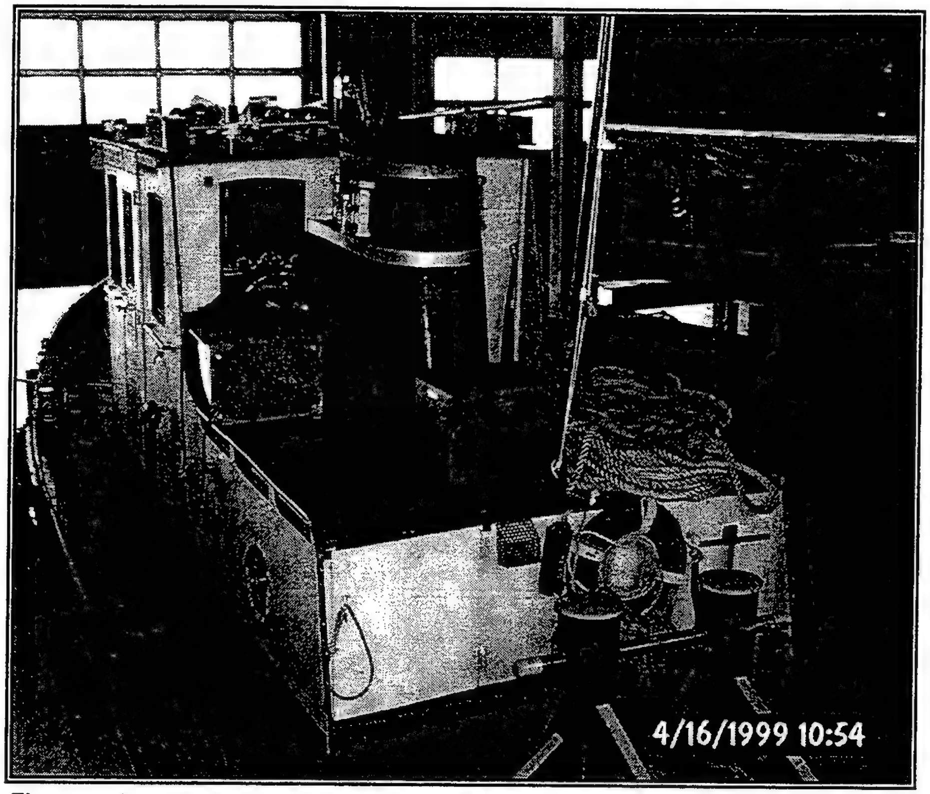

Figure 4. Tug docked in boathouse.

Problem

High Electrical Use

The floating plants consume a substantial amount of installation electricity that is used by resistance heaters for space conditioning. At the present time, however, this appears to be unavoidable. Maintaining the worker comfort and space conditioning requirements in the interior cabin areas of these boats is quite challenging. There are two separate functions of the space heaters: (1) to provide temperature control (heat) during winter conditions, and (2) to provide humidity control when outside conditions start to moderate. During these latter conditions, the workers are forced to overheat the interior areas to ensure that the dew point is not exceeded on interior surfaces, tools, winches and cranes, and electronic equipment.

Temperature Control

The cabin walls and interior areas below deck are made of plate steel, and the walls and ceilings are insulated. This makes temperature control during the winter expensive because of: (1) the low R-value of the walls, and (2) the fact

that the interior air temperatures must be kept substantially warmer than normal to compensate for human body radiant loss to the extremely cold surfaces. As the surface temperatures rise with outside air, the amount of radiant cooling near the occupants decreases and comfort can be achieved at a lower interior temperature. Without the means to automatically control temperatures, the occupants set the heat for the requirement in the morning and late day, and open hatches midday when they get too warm.

Humidity Control

According to Mr. Hallquist, humidity is a major problem with the operation of the floating plants. The problem is caused because the water that the boats sit in stays very cold much later in the season than the air does, and the conductive nature of the cabins and hull keeps the interior surfaces cooler than the warmer air that starts to occur as spring arrives. Since this air is often saturated, the dew point is easily achieved on the interior surfaces of the boats and large amounts of condensation result. Workers told numerous stories of electronic (and other) equipment damaged by moisture, lost work time due to cleaning and oiling tools, and safety problems due to wet cables on winches and cranes. To control this, personnel are forced to overheat the cabins to absorb the humidity, and then open doors and windows in an attempt to achieve comfortable working temperatures. The best way to efficiently account for this and simultaneously save installation energy is to install a control system to regulate electric heaters in response to either temperature or humidity requirements.

Insulating the Cabins

Spray-on bonded cellulose and fiberglass marine hull board has been installed on the interior ceiling and walls of the derrickboat, S/V Bray and the two harbor tugs. The insulation is not continuous in any of the plant due to the problems previously noted. This has helped the thermal comfort situation, but has caused other problems. First, the large temperature difference that sets up across the insulation allows the dewpoint to be reached inside the insulation. Under humid conditions, this causes moisture retention and mold growth in the insulation, which also deteriorates its thermal properties. Second, the choices for insulation materials are limited by fire and marine-rating restrictions. And third, a safety problem has been noted on the deck areas above which insulation has been placed. In many cases, the heated side of the deck plate has been insulated. The supporting angle iron framing projects below the insulation and transmits heat to the deck. The frost on the deck melts in long stripes above the framing so that moisture runs and freezes over the insulated plate. As a consequence, the deck develops ice, which causes a slip hazard. These interrelationships and compet-

ing effects make the use of insulation a problem. The use of insulation actually makes the decks more dangerous from accumulated ice and frost

Proposed Solution

CERL engineers recommend the design and installation of a direct digital control system (DDC) to control the temperature and humidity conditions inside the floating plant cabins, and to monitor critical conditions inside the cabins such as valve freezing, high water (water leakage), and lack of power or heat. The pedestals are already equipped with LAN drops that will provide the communications between the warehouse office and the docked plants. The design of such a system should be done by an independent, third-party engineering consulting firm that specializes in DDC control systems and is familiar with a number of vendors products. CERL has experience with dealing with such firms, and is available to work with Detroit District and Mr. Hallquist to define the control requirements for this project.

5 Central Heating Plant

The facility tour was provided by Mr. Ricky Southwell, Plant Supervisor.

Description

The plant consists of three, 150-hp fire-tube boilers (Figure 5) manufactured by Superior Boilers. The plant went into operation in 1996. Output is rated at 5,175 lb/hr steam at 150 max pressure. The plant's primary function is to provide direct steam heat to the locks to keep ice off the gates. When the plant is on-line it also provide steam to some of the buildings for space heating. The plant was offline for the spring/summer season. The system will typically use about 4,000 to 5,000 gal of water in an 8-hour period. The water conditioning system is designed to provide a maximum of 30 gal/min to the DA tank. There are three feedwater pumps rated at 7 ½ Hp, 3450 rpm, 30 GPM. The feedwater pumps are Lockwood Products, Atlanta, GA model HG08-3

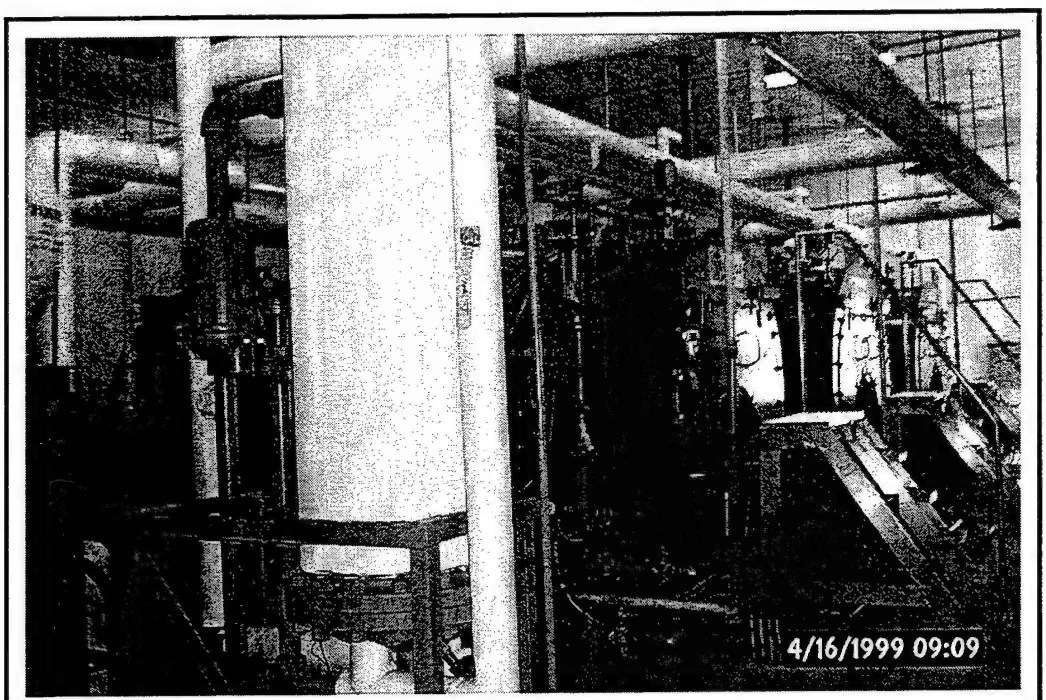

Figure 5. Steam plant boilers.

Problems

Feedwater System Deaerator

A potential problem exists in the feedwater system. Apparently, the original design had sought to obtain make-up water at around 50 °F from new ground water wells. These wells were removed from the project because it was determined that they were not cost effective. Instead, make-up water was obtained from the water passing through the locks. This water is very close to 32 °F while the plant is in operation. There is a small make-up water preheat system which uses continuous blowdown water from the boilers. However, this system is not large enough to prevent very cold water from entering into the Deaerater (DA) tank, causing thermal shock and preventing the DA from functioning correctly. The DA tank head temperature has been seen to drop from 230 to 180 °F.

The purpose of a deaerating heater (deaerator, see Figure 6) is to remove non-condensable gases and dissolved oxygen from the feedwater. A properly operating deaerator will have no more than 10 ppb (parts per billion) O_2 in the outlet water. Deaerators are subject to thermal cycling and corrosion. Proper operation of deaerators is extremely important because of their critical function in protecting the boiler system from corrosion. Catastrophic failure of deaerators is usually attributable to cracks forming longitudinally and transversely to the heat affected zones of the welds. Deaerators are potentially a great danger because of their location at the top of the heating or power plant. To ensure that deaerators provide safe reliable service, they require periodic visual inspections of their internal and external surfaces. If visual inspection reveals cracking, then a company specializing in deaerator inspection must perform an ultrasonic examination of the entire vessel and wet fluorescent magnetic particle examinations of the heat affected zones of the welds before certification to determine if continued operation of the vessel is safe. Repairs must be subjected to post-weld heat treatment and hydrostatic testing before certification.

Particular attention should be given to deaerator venting practice. Venting should be held to the minimum required to preclude oxygen entrainment in the feedwater. When intermittently operating condensate pumps are used, look for any tendency toward the creation of a vacuum when a pump starts. If this happens, the installation of a small continuously operating, float throttled, condensate pump (in parallel with intermittently operating pumps) will ensure a condensate flow at all times. If there are a number of intermittently operating condensate pumps, it may be possible to convert one of them (if of small enough capacity) to continuous throttled operation.

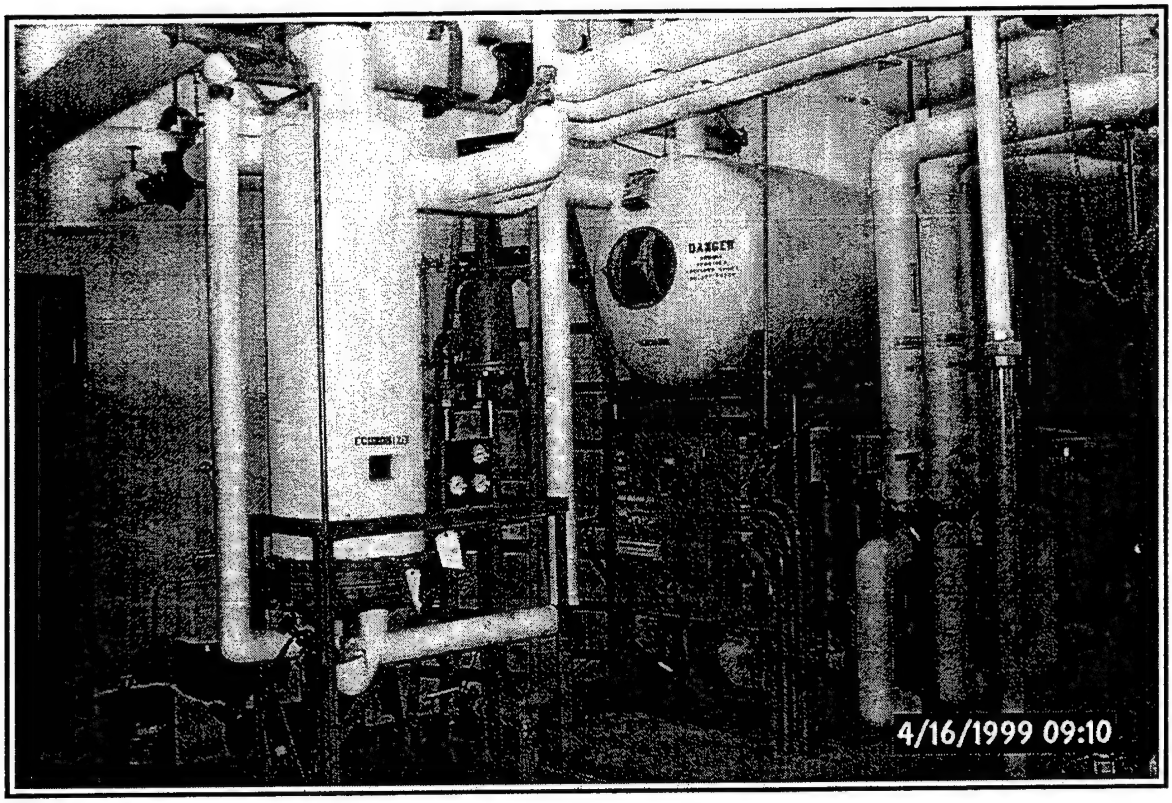

Figure 6. Steam plant deaerator and blowdown heat exchanger.

Feedwater Pumping System

Another potential problem existing in the feedwater pumping system. The pumps may be cavitating and experiencing extensive cycling. This problem may be caused by the DA tank being located too low in elevation above the pumps. Low elevation can result in NPSH at the pump inlet which causes cavitation. In designing these systems, the minimum recommended elevation of DA tanks above the feedwater pumps is 7 ft. The existing DA tank is only about 4 ft above the pumps.

The boilers also experience load surges from the steam users, which causes low water problems at the boilers. Surge tanks are often installed ahead of feedwater heaters to prevent surging problems

The external water treatment system (Figure 7) is a typical sodium zeolite softening system. This system may also be experiencing surge problems from rapid demands by end-use equipment, which could be solved by using a surge tank.

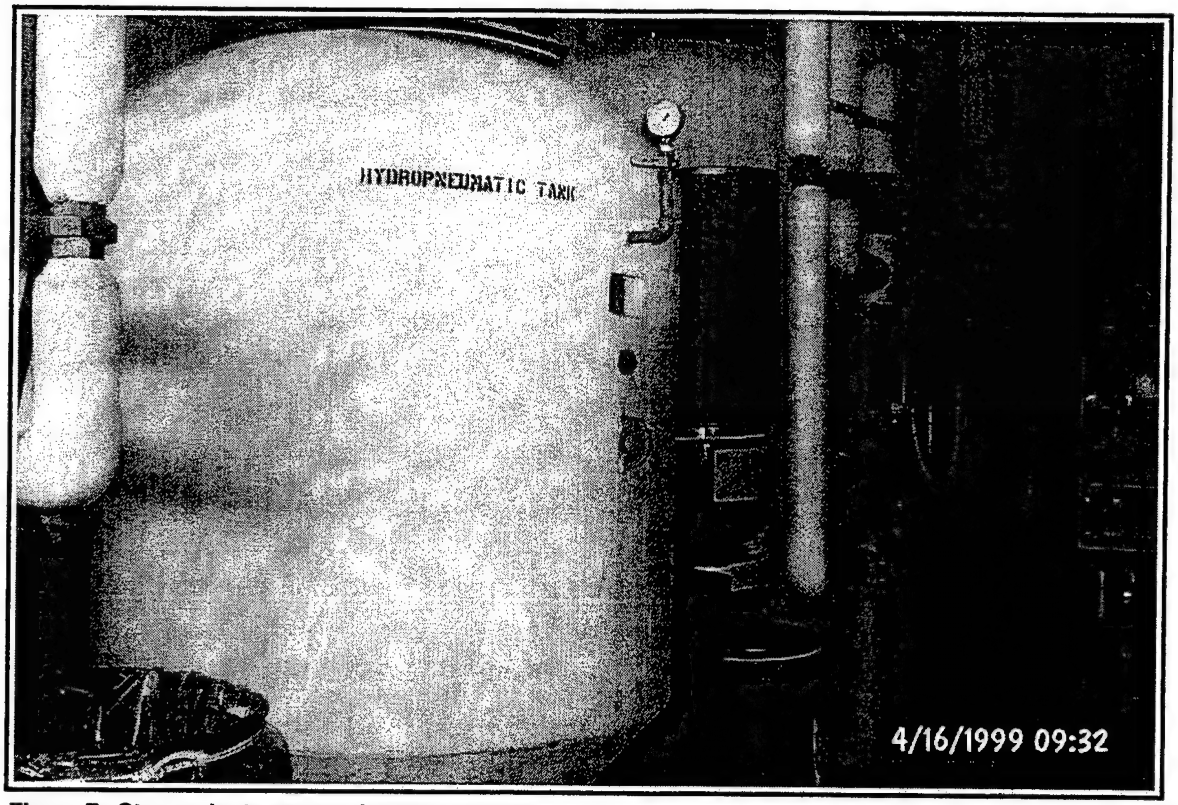

Figure 7. Steam plant – external water treatment system.

The internal water treatment program is reviewed twice per year by the water treatment chemical supplier. The operating staff also checks the boilers 3 times/week (Monday, Wednesday, Friday). Sulfites are added at the boiler and are maintained between 60-30. P-alkalinity is maintained at 400-600. Conductivity is maintained at 2000-2500. The internal water treatment should be adequate for steady state operation, but may become deficient if the boilers experience large fluctuations in steam demand.

The steam distribution system is located in tunnels that run alongside the locks (Figure 8). No condensate is returned to the boiler plant. There were no signs of pipe leakage or damage in the tunnels.

Recommendations

- Boiler system design should be assessed to determine corrections for DA and feedwater problems.
- Boilers should be inspected/tuned-up to ensure efficient operation.
- Boiler operators should receive onsite training (which could be combined with the boiler tune-up/inspection activity).
- Boiler lay-up procedures should be reviewed to optimize equipment life.

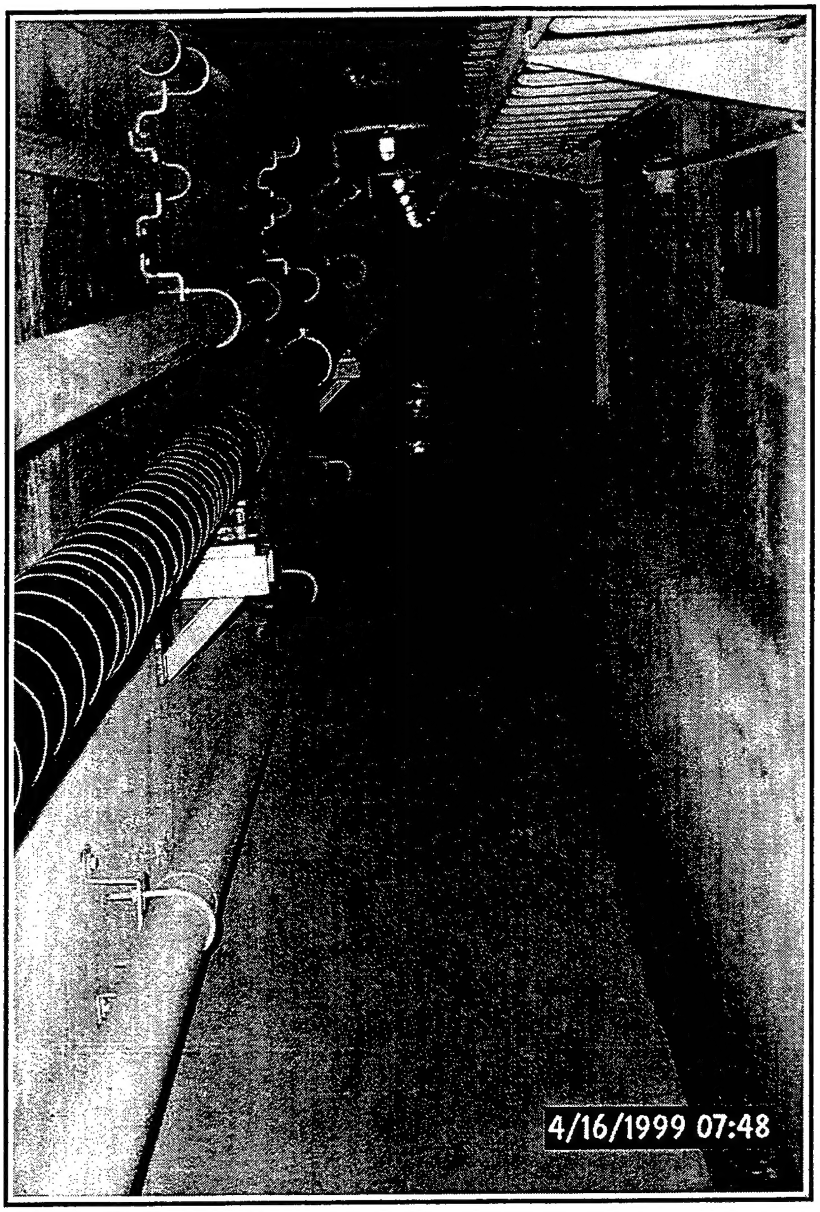

Figure 8. Utility tunnel.

6 Air Compressors for Ice Control

Description

Three 350 hp electric air compressors supply air for a bubbling system to control ice blockage at the gates. The bubbling system is needed during the spring and fall. Two air compressors will run 24 hrs/day when ice is present in the locks. Space heating for the Compressor Building is provided by waste heat from the compressors with back-up from electric heaters. The compressors were not in operation during the site visit, but appear to be well maintained.

Recommendation

Conduct a distribution leak inspection and repair lines, if required.

7 Summary and Recommendations

This study evaluated the facilities at the Soo Area Office, Sault Ste. Marie, MI for energy efficiency, and makes the following recommendations for improvements in energy efficient operations:

1. *Lighting*.
   a. Replace existing fluorescent lighting systems with T8/electronic systems at the next time of building rehab or wide-scale lighting replacement.
   b. Consider increasing light levels in the utility tunnel, and installation of a lighting control system for the utility tunnels running parallel to the locks.
   c. Continue to monitor space heater control condition in remote structures to ensure that controls are working as intended and are not set too high.
   d. Upon failure of existing systems, replace warehouse lighting (Figure 1) with T8/electronic ballasted luminaires.

2. *Buildings*. Because of the use pattern of frequently opened overhead doors, a more energy-efficient approach to space heating would be to replace the overhead steam-fed unit heaters with gas-fired infrared heaters. However, note that the cost-effectiveness of this change *may not justify the expenditure of energy conservation funding*.

3. *Floating Plants*. Install a direct digital control system (DDC) to control the temperature and humidity conditions inside the floating plant cabins, and to monitor critical conditions inside the cabins such as valve freezing, high water (water leakage), and lack of power or heat.

4. *Central Heating Plant*.
   a. Boiler system design should be assessed to determine corrections for DA and feedwater problems.
   b. Boilers should be inspected/tuned-up to ensure efficient operation.
   c. Boiler operators should receive onsite training.
   d. Boiler lay-up procedures should be reviewed to optimize equipment life.

5. *Air Compressors for Ice Control*. Conduct a distribution leak inspection and repair lines, if required.

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